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# Multiple-Charge-State Steering in the RIA Driver Linac

R&D Category: Driver Beam Dynamics

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(paper 2.0.5)

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# *Reasons for a Robust Steering Algorithm*

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- ❖ Multiple charge states: strongly affected by misalignment errors leading to effective transverse emittance growth.
- ❖ Superconducting driver linac: 1. Large number of components
- 2. Limited space for diagnostics.
- ❖ Need of frequent machine-settings retuning to accommodate many different ions.
- ❖ Algorithm should be an integral part of TRACK to facilitate beam loss studies along the accelerator.
- ❖ Should be capable of being implemented in real machines.

# *Steering Algorithm Requirements*

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- Control effective emittance growth
- Reduce large trajectory excursions

One-to-one correction algorithm used in many machines not possible:

- Need to correct both position and angle ( $\varnothing \sim 60^\circ$ )
- Focusing solenoids introduce coupling
- Many-to-one correctors to Beam Position Monitors (BPMs)

# *The Method*

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- Measure  $x$ ,  $x'$ ,  $y$ , and  $y'$  at BPMs
- Apply known deflections (kicks) to the trajectory
- Measure the new  $x$ ,  $x'$ ,  $y$ , and  $y'$  and calculate the differences
- Measure beam responses to induced kicks
- Find  $\theta$  that minimizes  $\Phi \propto (X + R\theta)^2$
- Apply steering



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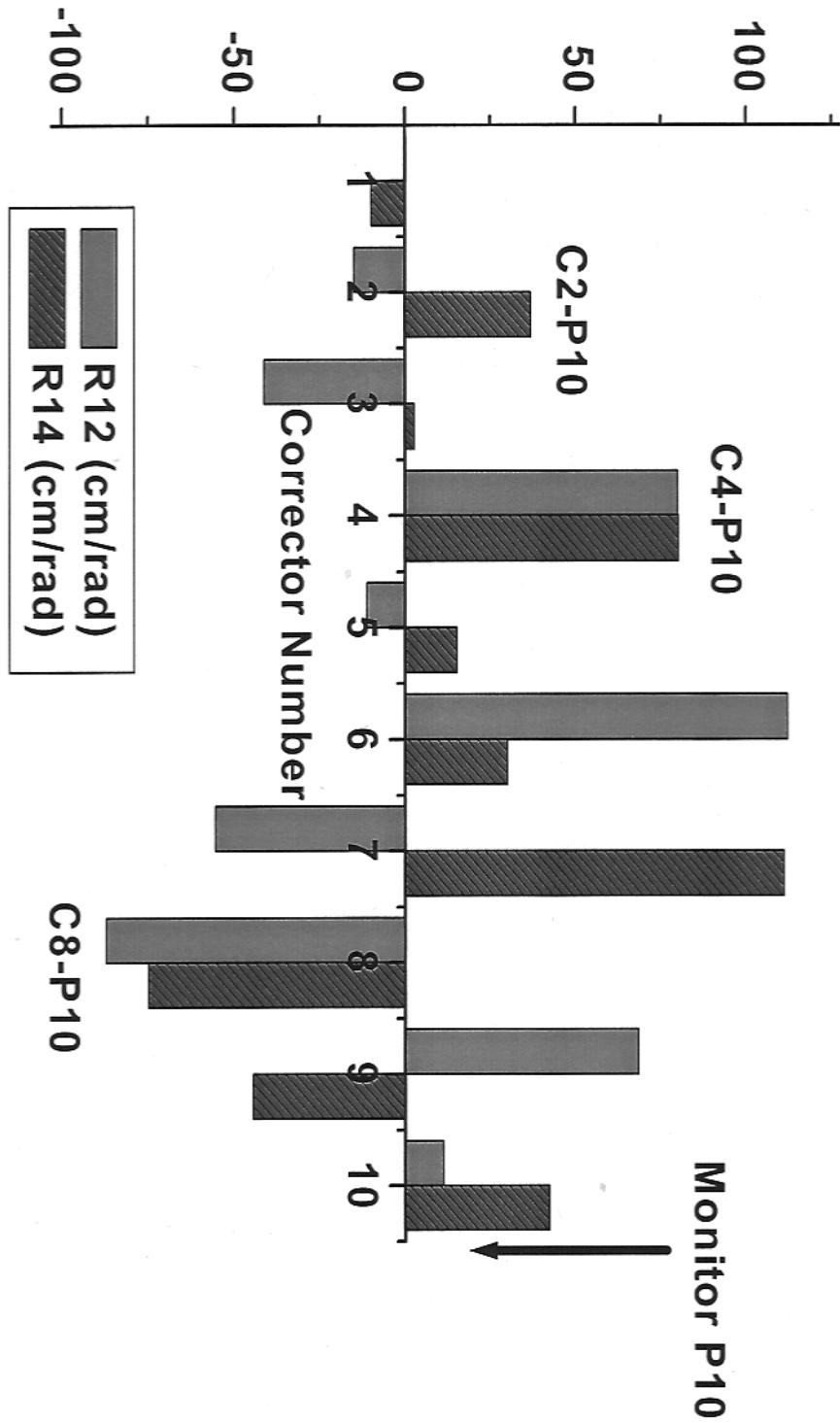
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# *Transfer Functions in the Prestripper: Example*



# *Misalignments and Correction Schemes*

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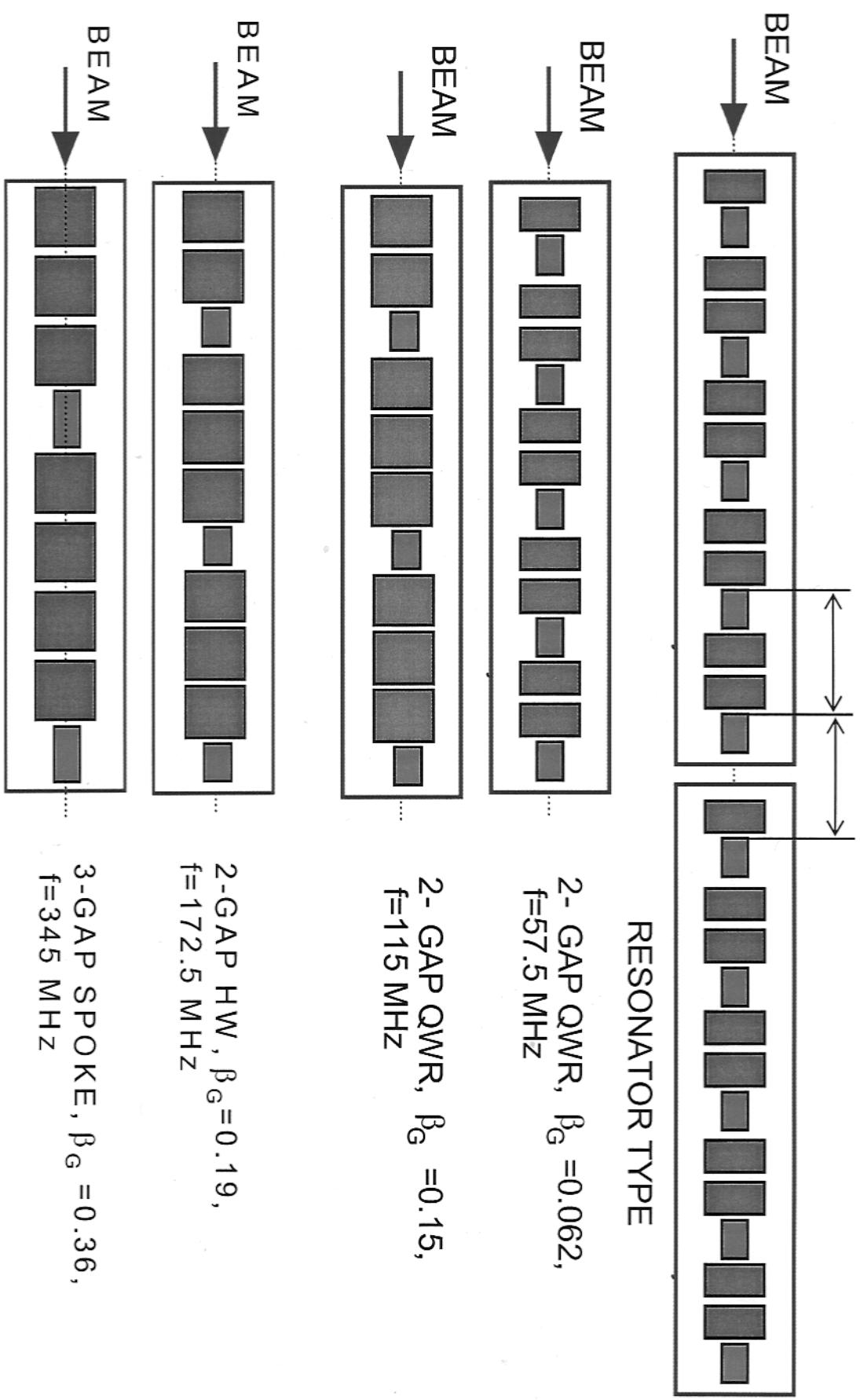
**Random Misalignments of Solenoids and Cavities:**

**Tolerance up to 1-mm displacements established**

**Two correcting schemes:**

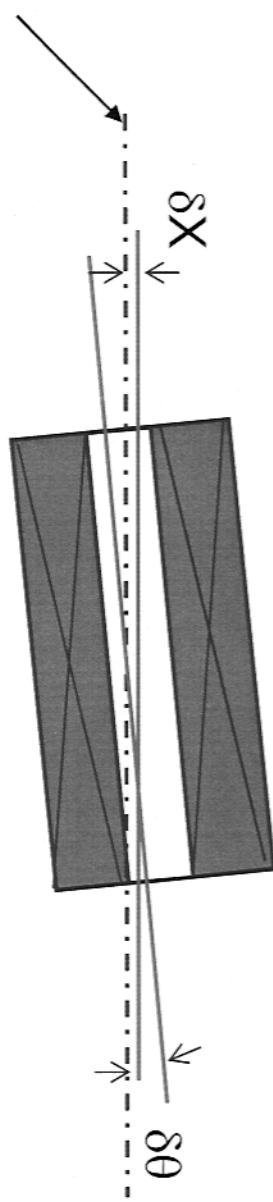
- one corrector at the end of each cryostat
- one corrector every other two solenoids
- one monitor in the intercryostat space

# Accelerating-Focusing Lattice in the RIA Linac



# Misalignment of Focusing Elements

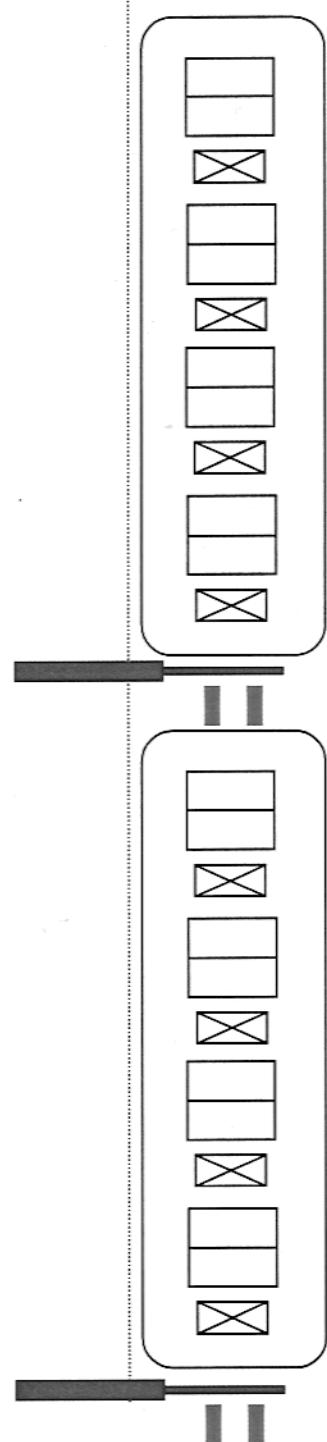
## Misaligned solenoid



Linac axis

$$\delta X = \pm 300 \mu\text{m}, \quad \delta\theta = \pm 0.2 \text{ mrad}$$

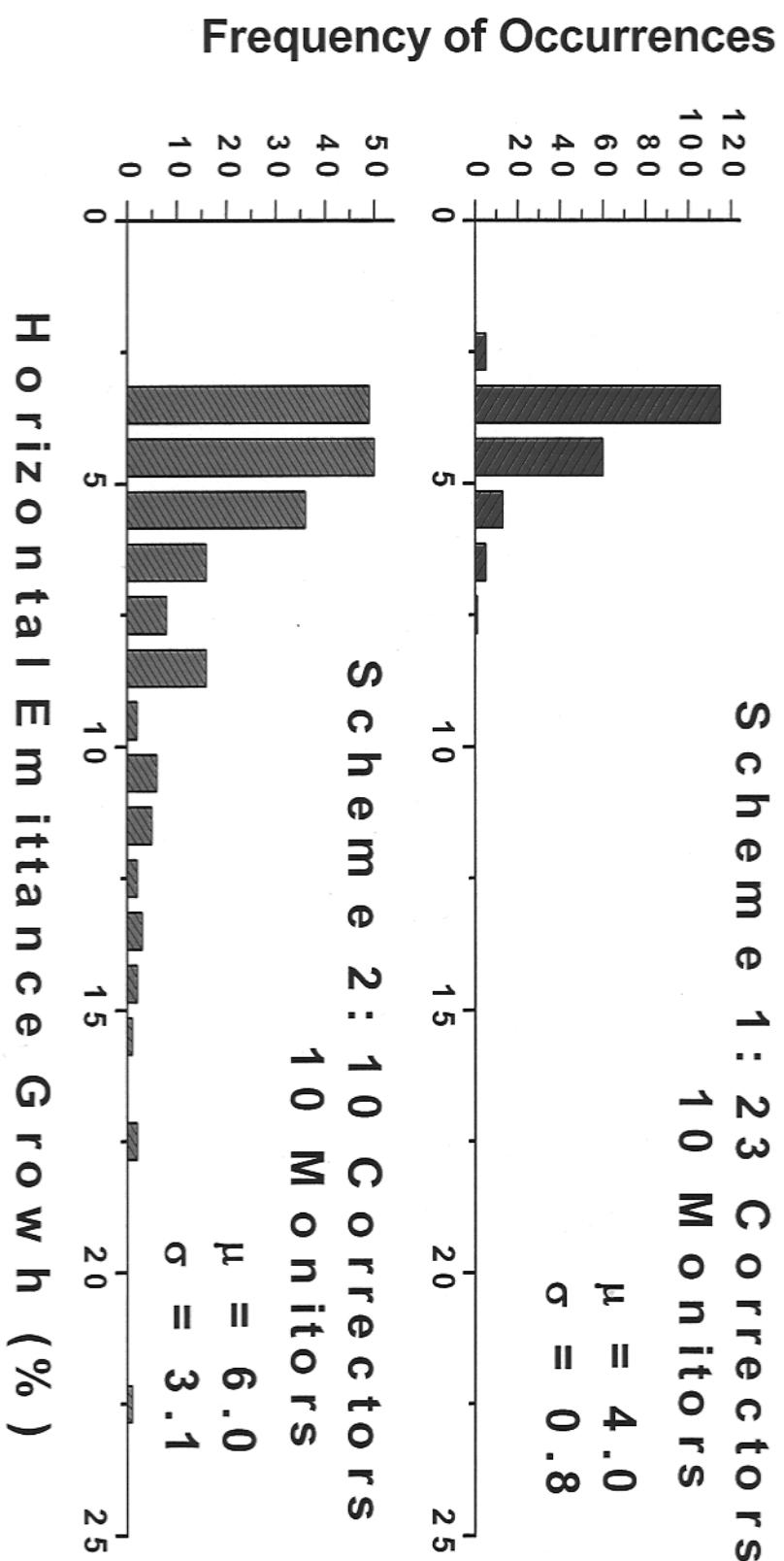
## Cryostat



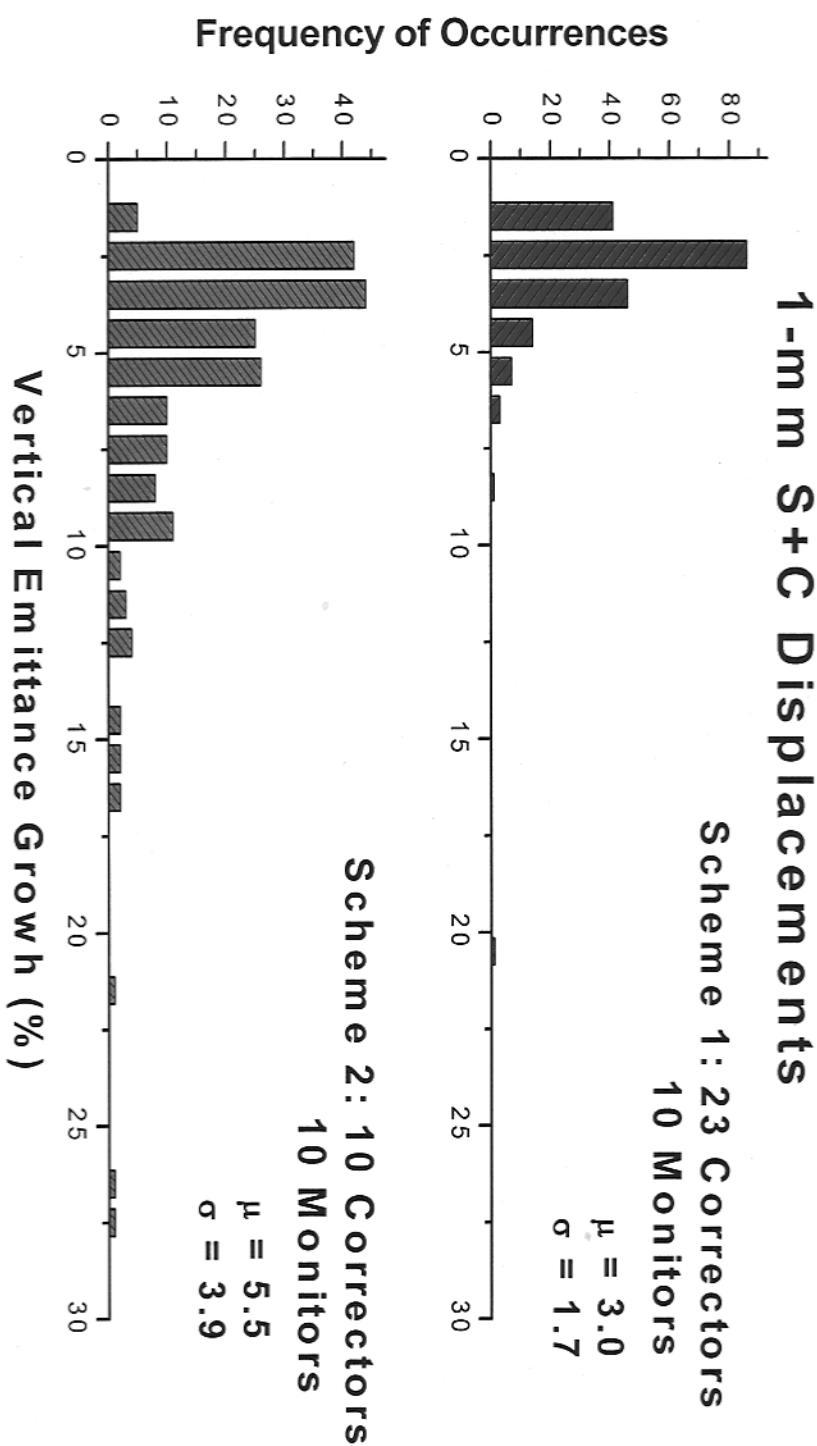
## BPM/Profile + Steering magnet

# Corrected Normalized Emittance: Horizontal

Prestripper: 1-mm S+C misalignments



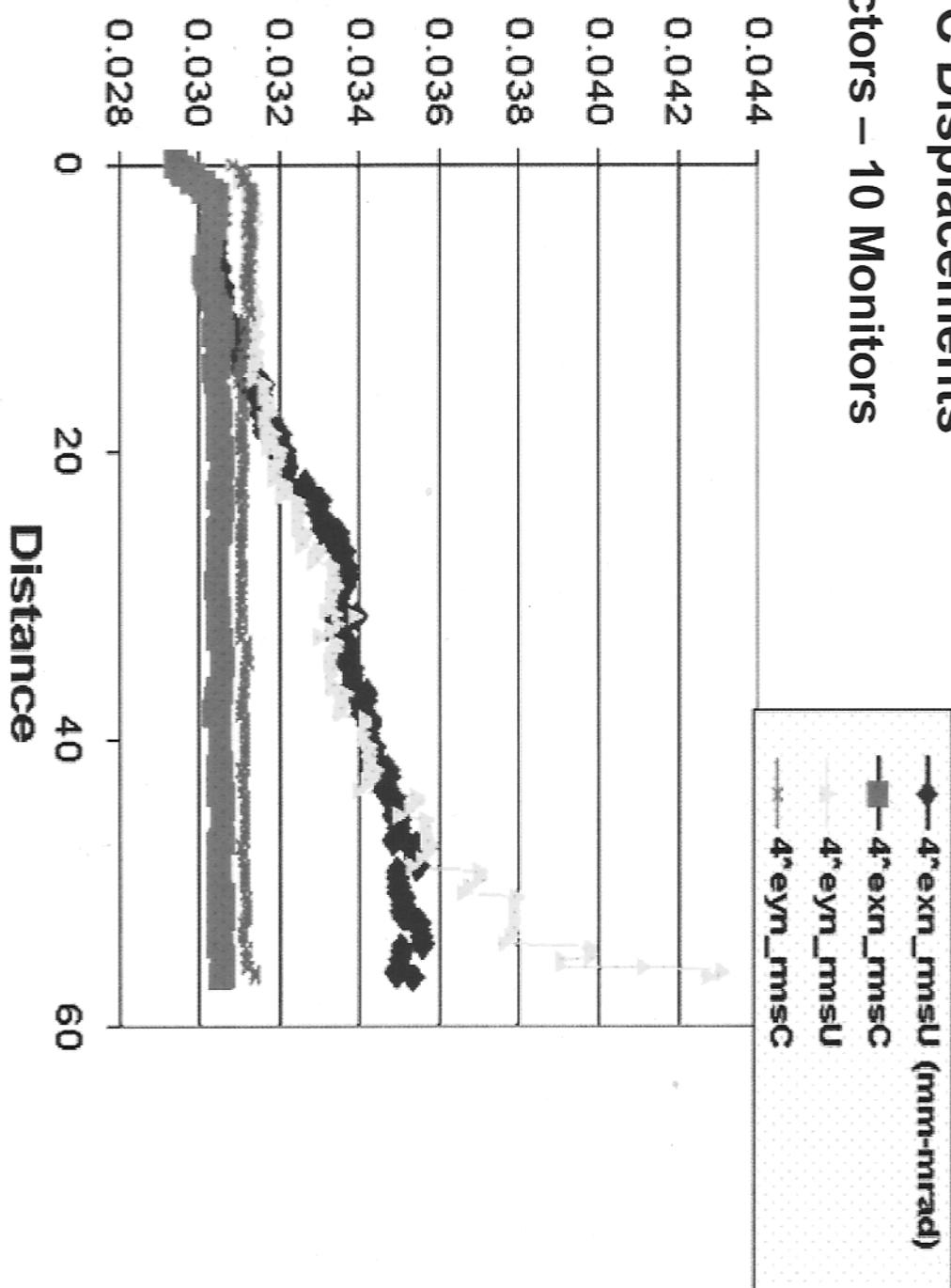
# Corrected Normalized Vertical Emittance :



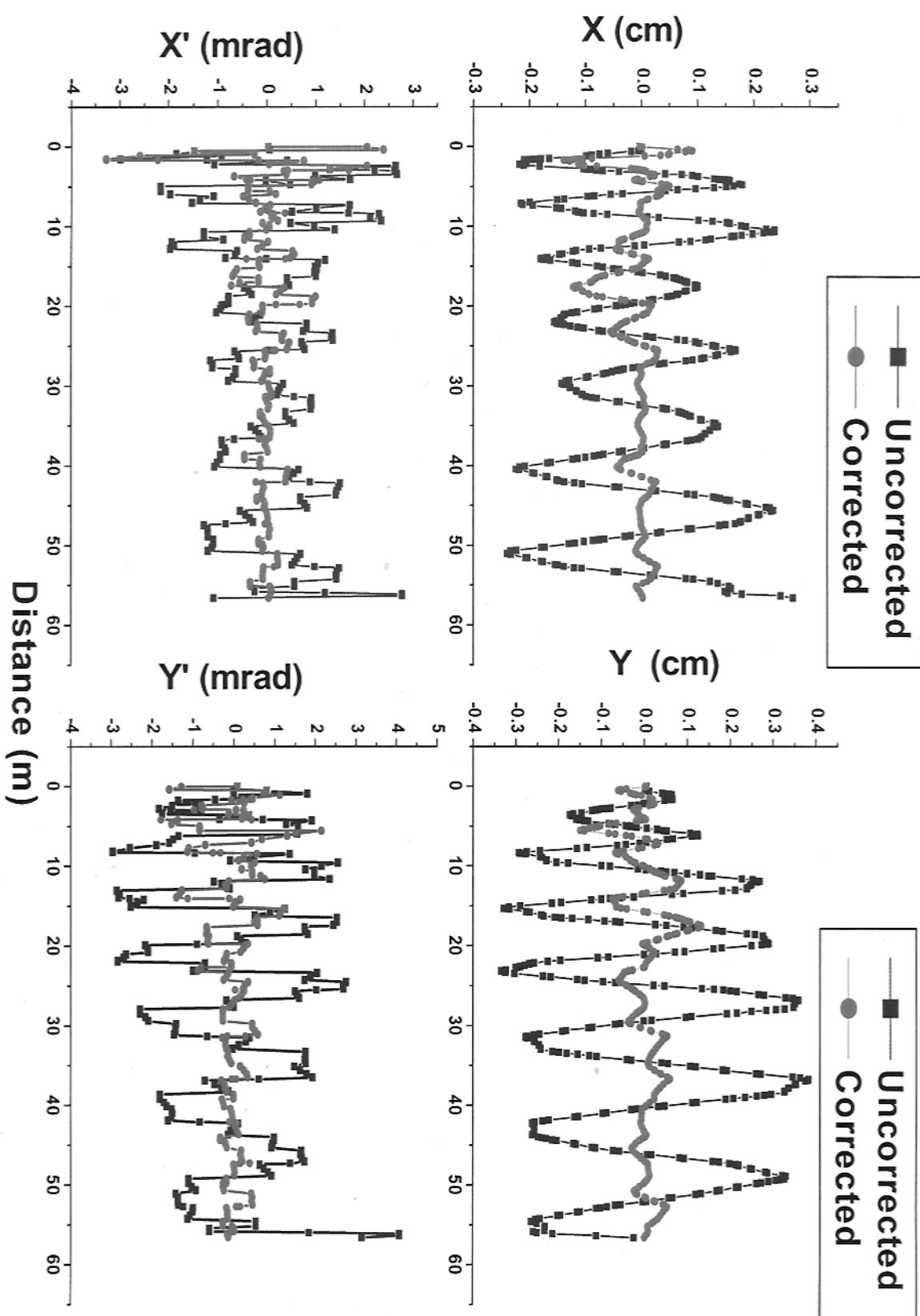
# Effective Emittance Growth: One Seed

## 1-mm S+C Displacements

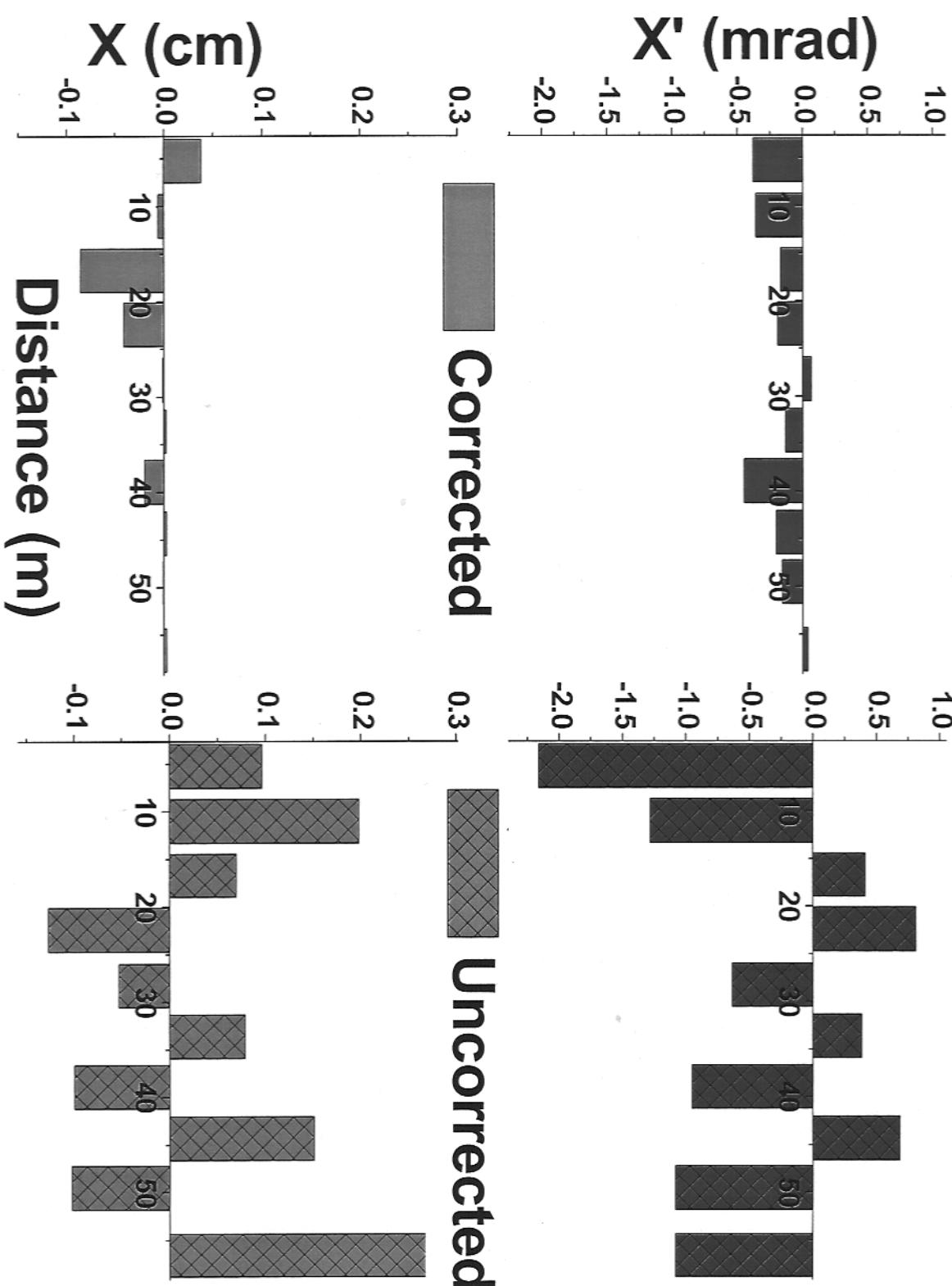
### 23 Correctors – 10 Monitors



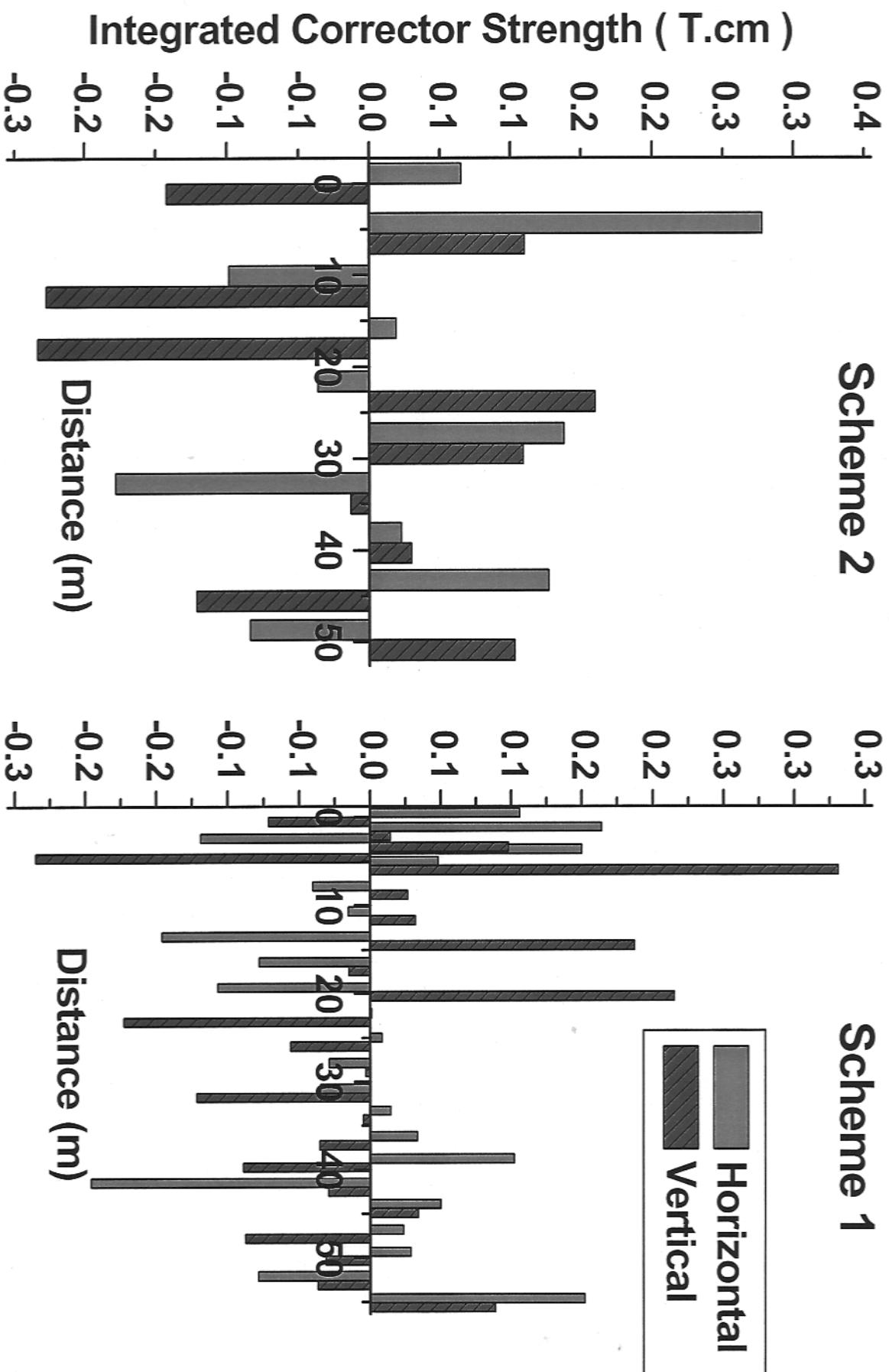
# Centroid Trajectories



# Trajectory Coordinates at the Monitors



# *Integrated Corrector Strengths*



# Summary

Which scheme?

## Scheme 1

- ❖ More steering:  
better correction
  - Less steering: less  
efficient correction
- ❖ More magnets:  
more expensive
  - Less magnets:  
less expensive

## Scheme 2:

# *Future R&D*

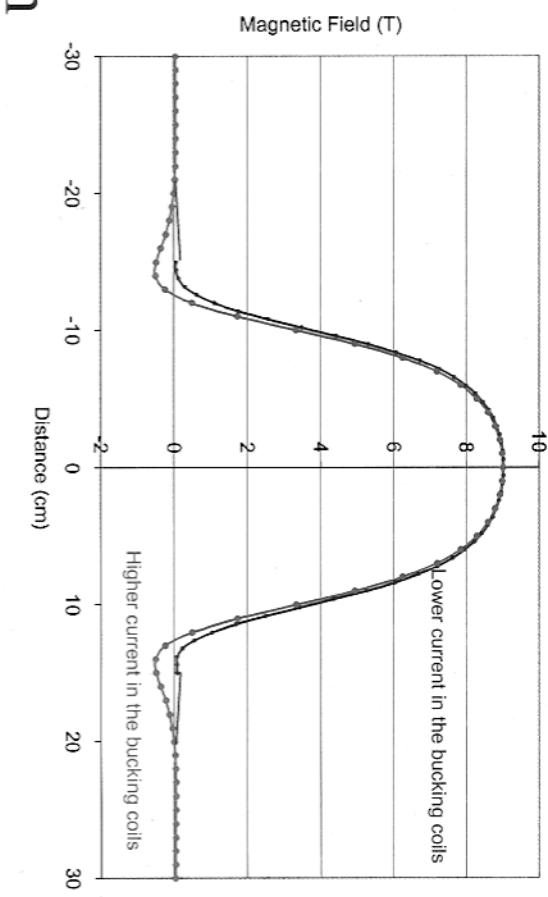
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- Experimental tests on ATLAS: validate effectiveness of algorithm.
- Incorporate realistic steering from dipole coils mounted on solenoids in the simulation.
- Establish a comprehensive tolerance budget.

## Focusing by SC solenoids:

- proven technology with SC resonators;
- multi-q beam is less sensitive to mismatched conditions;
- the fringing fields can be suppressed by bucking coils;
- alignment of the solenoids should be easier.

### Compact 9 Tesla SC Magnet Assembly

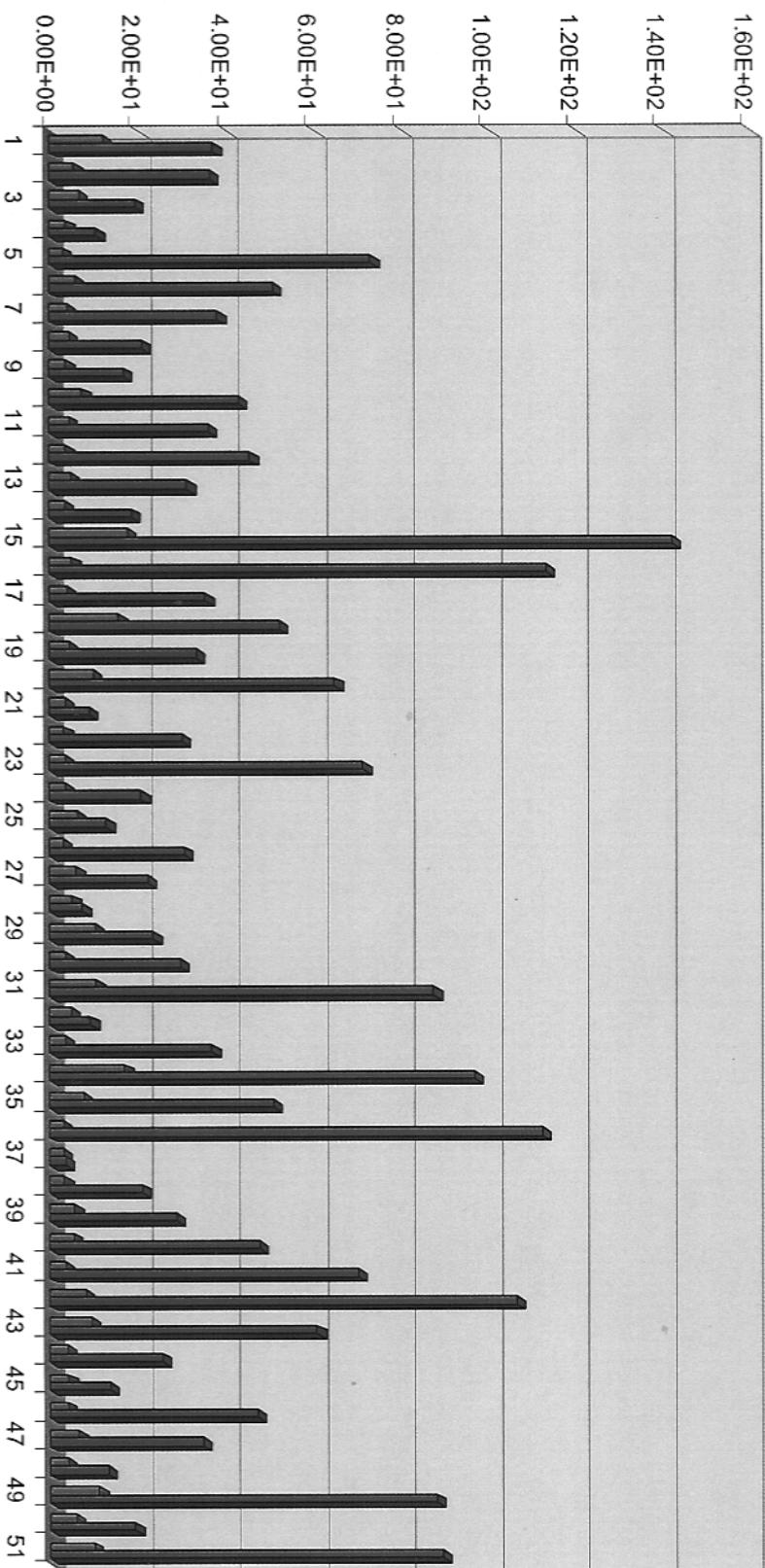


# Emittance Before and After Correction

Prestripper:10 Corrr- 10 Mon

1-mm S+C Displacements

- EmitGrX -Corrected
- EmitGrX-Uncorrected



# The Correction Algorithm

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$$\tilde{\mathbf{x}} = \mathbf{x} \quad R11 + \mathbf{x}' \quad R12 + \mathbf{y} \quad R13 + \mathbf{y}' \quad R14$$

$$\tilde{\mathbf{x}}' = \mathbf{x} \quad R21 + \mathbf{x}' \quad R22 + \mathbf{y} \quad R23 + \mathbf{y}' \quad R24$$

$$\mathbf{x} = \mathbf{x} \quad R11 + (\mathbf{x}' + \delta\theta) \quad R12 + \mathbf{y} \quad R13 + \mathbf{y}' \quad R14$$

$$\mathbf{x}' = \mathbf{x} \quad R21 + (\mathbf{x}' + \delta\theta) \quad R22 + \mathbf{y} \quad R23 + \mathbf{y}' \quad R24$$

$$\Delta \mathbf{x} = \frac{R12}{\delta\theta} \quad \Delta \mathbf{x}' = \frac{R22}{\delta\theta}$$



# *Effects of Sol Misalign/ on Monitor Precision*

| Solenoid    | Monitor  | Solenoid | Monitor  |
|-------------|----------|----------|----------|
| X 0.00123   | -0.02541 | 0.00358  | -0.04883 |
| X' -0.4750  | -0.47580 | -0.93597 | -0.93597 |
| Y -0.01458  | -0.03631 | -0.01271 | -0.05712 |
| Y' -0.38802 | -0.38802 | -0.9303  | -0.79303 |

$$\begin{aligned}\Delta Y(\text{sol}) &= \\ &0.00187\end{aligned}$$
$$\Delta Y(\text{mon}) = \\ = 0.02087$$

# Medium - Energy Section

